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Optimum Structure with Homogeneous Optimum Truss-like Material

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ABSTRACT

This paper presents a new formulation of concurrent topology design of structure and material, in which the micro-structure of material is assumed uniform in macro-scale to meet the manufacturing requirement. Throughout the development history of structural topology optimization, the conception of micro-structure of material is introduced to implement structural topology optimization as well as concurrent optimization of structure and material. For structural topology optimization, researchers aim at black-white design, and the area of material with complicated micro-structure is suppressed by various penalty approaches. For concurrent optimization of structure and material, material micro-structures are different from point to point in the final design obtained by optimization, which gives rise to insurmountable manufacturing difficulty. Since that, the micro-structure of material in structural topology optimization is merely a mathematical treatment for the ill-posed problem. However, in engineering practice there is a need for concurrent topology design of structure and material, in which the micro-structure of material is assumed uniform in macro-scale to meet the manufacturing requirement. In order to simultaneously implement the topology design for macro-structure and homogeneous micro-structure of material, SIMP is utilized in both scales with the definition of two classes design variables, i.e. macro-density distribution within the design domain and micro-density distribution within the homogeneous unit cell. The two scales are linked by performing the homogenization procedure in the micro-structure which determines the elastic material properties used in macro-scale analysis. Numerical experiments for a number of examples demonstrate the advantage of truss-like material. Furthermore, another case is also discussed where the direction of the principal axis for material is taken as an additional design variable. Minimum compliance topology optimization of an elastic continuum is considered in the formulations, and SQP (Sequential Quadratic Programming) method is adopted. To avoid checkerboard patterns, a variant perimeter constraint is used in the micro-scale design. The attached figure from one example shows that an optimum structure with homogeneous optimum truss-like material is obtained under prescribed boundary conditions and material volume. The assumption of uniform configuration of micro-structure may lead to an easier manufacturing process, thereby greatly increasing the possibility of engineering application.